Expanded Color Gamut Printing for a Narrow Web Flexographic Press

Akshay Joshi[1], Kiran Deshpande[2], and K.Panthala Selvan[3]

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Abstract

Expanded Color Gamut (ECG) printing has been growing in the packaging printing industry globally. In this study, ECG printing was implemented with CMYKOGV inks for a narrow-web Flexographic printing process. This paper explores the key aspects of implementing ECG printing and performs gamut analysis by comparing the gamuts of CMYKOGV and CRPC6. The results show that the ECG printing process can be successfully implemented for a narrow-web Flexographic process with an acceptable accuracy of spot colors.

Introduction

The global self-adhesive labels market size is projected to grow from USD 46.5 billion in 2020 to USD 59.2 billion by 2025 [1]. With the expanding pool of brand choices in the fast-moving consumer goods (FMCG) Industry, brand managers and designers are searching for ways to attract customers to their respective brands. Flexography printing is a widely used process for label printing as it provides consistent color reproduction at greater machine speed.

Colors used in packaging of the product contribute the highest percentage to the buying decision of consumers. Traditionally, the CMYK process can produce a limited range of colors, hence spot colors have been used for achieving colors outside the CMYK gamut. However, printing with spot colors is not cost-effective and comes with its own challenges such as higher job changeover times and wastage [2].

There arises a need to implement the Expanded Color Gamut (ECG) printing that utilizes seven colors namely CMYKOGV. There have been several studies exploring the ECG printing [2-12]. The ECG printing gives a higher quality of

[1]P. V. G's College of Engineering and Technology and G. K. Pate (Wani) Institute of Management; [2]Siegwerk; [3]PressMan Solutions

work due to a wider range of colors and larger color gamut [3]. The increased gamut with ECG leads to more color options for labels and packaging.

The motivation behind this study is to realize the practical implementation of ECG printing for a narrow-web flexographic process and to understand the key aspects and challenges during the implementation.

Methodology

The experiment was conducted on Nilpeter FB - 430 Narrow Web Flexography Press. The substrate used for the work was 131 µm white polypropylene self-adhesive label having 310 mm width printed with Siegwerk 39-8 I 05 Series UV based inks. The trials were classified as Initial Run, Optimization Run, Fingerprinting Run, Characterization Run and Verification Run.

The objective of the Initial Run was to identify the optimum combination of plate and anilox including screening parameters. This was performed with varying anilox line screen and volume (800 LPI to 1000 LPI and 1.94 BCM to 3.4 BCM – see Table 1) for CMYKOGV with the plate resolutions of 133 LPI, 150 LPI and 175 LPI. Kodak Flexcel NX plates having 1.14 mm thickness with Tesa backing tapes (medium hardness) of 0.38 mm thickness were used. The color sequence followed for the runs was YCMKOGV.

Fig. 1 shows the layout design for the Initial Run. The solids were targeted based on the Idealliance® ECG (XCMYK+OGV) guidelines [13]. The tolerance for ECG calibration was 3.5 DE2000 and 2˚ Dh (hue angle). The measurements during the press-runs were done by TECHKON SpectroDens according to ISO 13655:2017 with M1 measurement mode [14]. The dot structures were analyzed at 50% with Generic Digital Microscope at 200 X magnification and assessed based on dot circularity.

Ink	Screen Ruling (LPI)	Volume (BCM)	Volume (cm^3/m^2)
Cyan	1000	2.4	3.72
Magenta	900	2.9	4.50
Yellow	1000	2.4	3.72
Black	800	3.2	4.96
Orange	800	3.2	4.96
Green	900	2.9	4.50
Violet	700	3.4	5.27

Table 1: *Anilox line screen and volume for ECG Calibration*

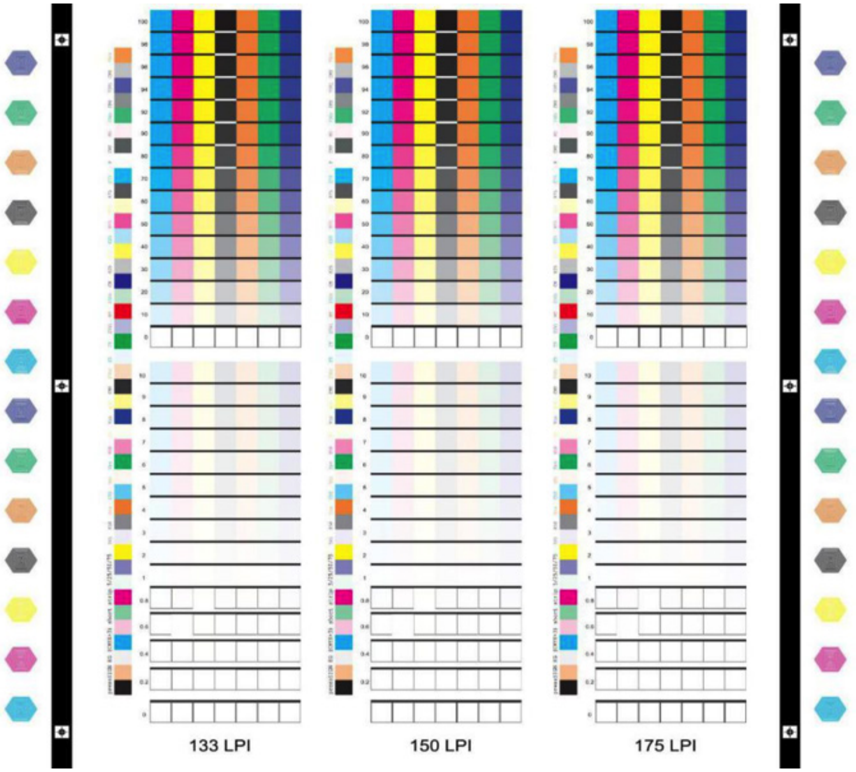


Figure 1: *Layout design for the Initial Run*

Optimization Run with the P2P51 X Target, color control strip (CMYKOGV), step wedges (1% to 100%), vignettes, slur target, tracker line and registration mark was conducted. The anilox rollers with hexagonal cell structure varying from 700 LPI/3.4 BCM to 1000 LPI/2.4 BCM were used for the run. The samples were checked for the solids, overprints, tonality and gray balance. The solids were measured on P2P51 X chart to verify the reproduction as per G7 tolerances. Furthermore, the run was also evaluated to confirm XCMYK reproduction.

The CMYK and OGV calibrations were performed using G7 method [15] and a linear SCTV calibration (ISO 20654:2017) respectively [16]. The press calibration curves were applied in the pre-press workflow and a set of new plates was prepared for the Fingerprint Run. The objective of the Fingerprinting Run was to apply the calibration. The tonality and gray balance reproduction of the Fingerprinting Run were compared with those of the Optimization Run.

The Characterization Run was executed by printing the CMYKOGV test form with 2000 patches generated in CGS ORIS X-GAMUT 4.0. An average profile from the measurement data of 5 printed charts was created with an automated color-measuring device. The gamut boundary of ECG was calculated and plotted in

Matlab and gamut volume of ECG was compared with the CRPC6 gamut using alpha-shapes method [17]. Gamut analysis was performed based on a number of gamut metrics [18].

The Verification Run comprised of a custom-made Test Chart in CGS ORIS X-GAMUT. It contained 1524 colors which were inside the CMYKOGV gamut. These colors were well-distributed across L*, a* and b* axes. The test chart was printed and measured using automated color-measuring device.

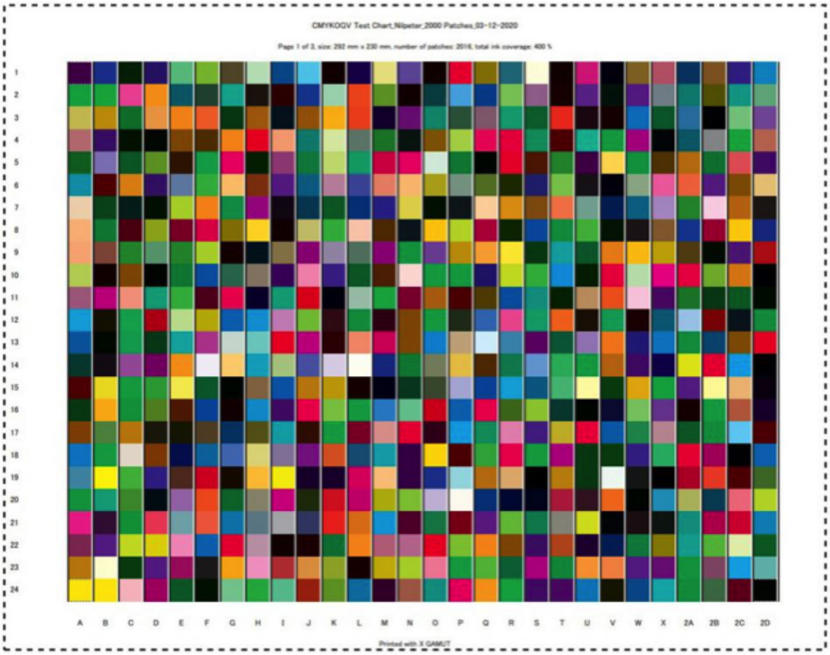


Figure 2: *Test chart for the Characterization Run – Page 1 of 3*

Results and Discussion

The dot structure was evaluated for CMYK with AM screening and OGV with both AM and FM screening. The dot structure (Figure 3 and 4) indicates uneven dot pattern at 133 LPI. The dot sharpness improved as plate resolution increased to 175 LPI for CMYKOGV. The higher dot spread with uneven spacing was observed for OGV at 133 LPI and 150 LPI with AM screening. Dot bridging was observed in FM screening and exhibited higher TVI as compared to AM.

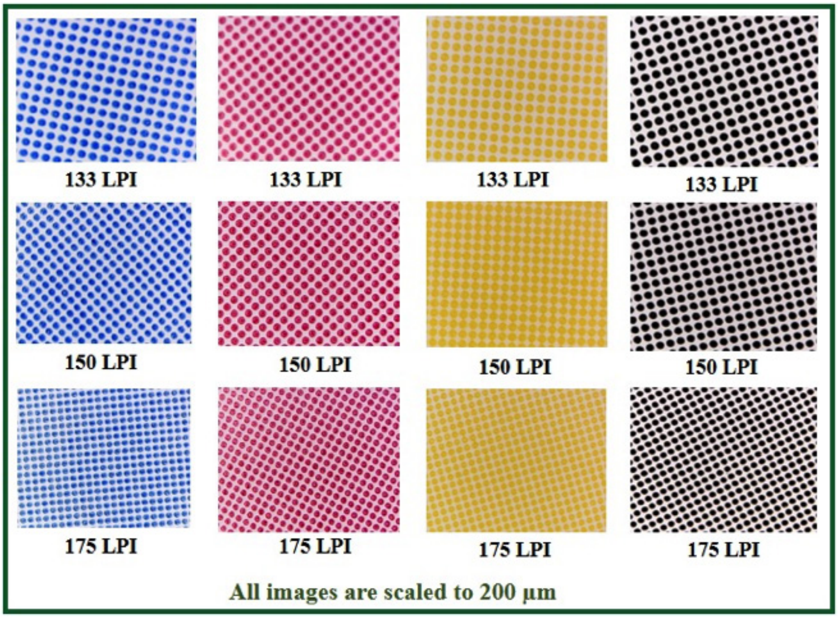


Figure 3: *Dot Structure of CMYK at varying plate resolutions*

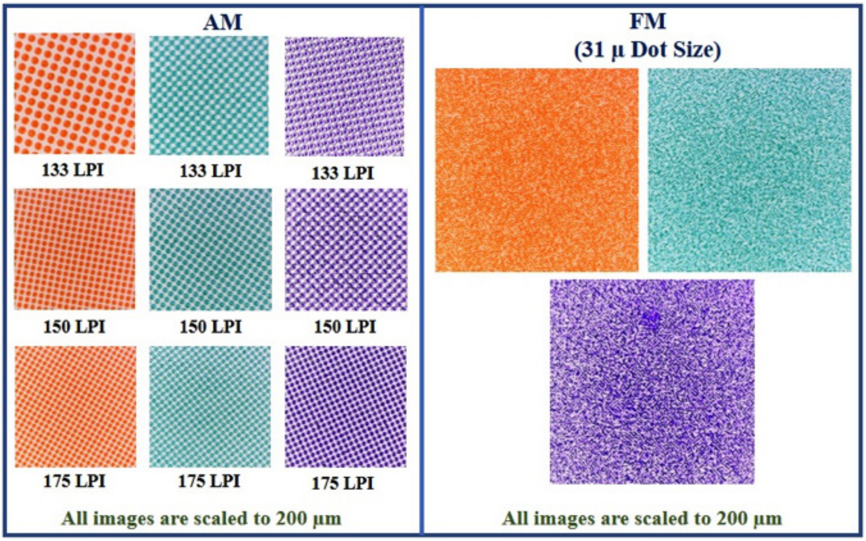


Figure 4: *Dot Structure of OGV at varying plate resolutions of AM and FM*

The 50% captured dots were processed through ImageJ software to calculate critical aspects of the dot like circularity and perimeter (Table 2).

The dot circularity refers to the roundness of dot and represented as

$$C = \frac{4\pi A}{P^2} \qquad \text{Eq. 1}$$

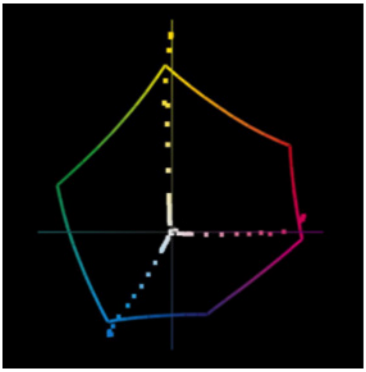
where A = area of dot and P = perimeter or the dot

Dot: 50%, AM Screening			
Color	**Line Screen**	**Dot Perimeter (µ)**	**Dot Circularity**
Cyan	133 LPI	85.292	0.783
Cyan	150 LPI	73.697	0.819
Cyan	**175 LPI**	**60.933**	**0.824**
Magenta	133 LPI	86.884	0.808
Magenta	150 LPI	80.08	0.827
Magenta	**175 LPI**	**61.944**	**0.834**
Yellow	133 LPI	83.159	0.84
Yellow	150 LPI	79.016	0.867
Yellow	**175 LPI**	**70.141**	**0.883**
Black	133 LPI	87.383	0.821
Black	150 LPI	82.521	0.853
Black	**175 LPI**	**80.404**	**0.869**

Dot: 50%, AM Screening			
Color	**Line Screen**	**Dot Perimeter (µ)**	**Dot Circularity**
Orange	133 LPI	92.245	0.875
Orange	150 LPI	81.619	0.878
Orange	**175 LPI**	**69.716**	**0.89**
Green	133 LPI	126.316	0.832
Green	150 LPI	88.042	0.851
Green	**175 LPI**	**69.919**	**0.854**
Violet	133 LPI	65.79	0.622
Violet	150 LPI	64.037	0.64
Violet	**175 LPI**	**62.441**	**0.642**

Table 2: *Dot Circularity for CMYKOGV*

Maximum dot circularity was observed at 175 LPI for CMYKOGV; thereby indicating the quality of the dot being printed. The solids and overprints were reproduced within the Idealliance® tolerance specifications. Hence, 175 LPI, AM screening was optimized based on L* a* b* C* h* and dot structure analysis and considered for further runs.



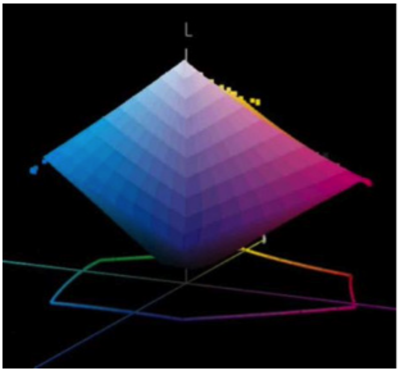


Figure 5: *2-D Plot (left) and 3-D Plot (right) of XCMYK Vs. CRPC6*

From 2D and 3D plot (Figure 5), it is evident that CMYK reproduction in Optimization Run has expanded as compared to CRPC 6 GRACoL 2013; hence confirmed the XCMYK reproduction.

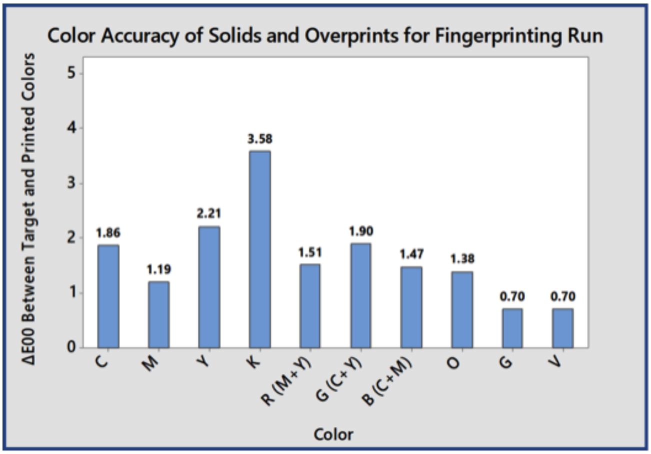


Figure 6: *Color Accuracy of Solids and Overprints for Fingerprinting Run*

Figure 6 shows the average accuracy for solids and overprints. All values were found to be within the tolerance as per Idealliance® specifications.

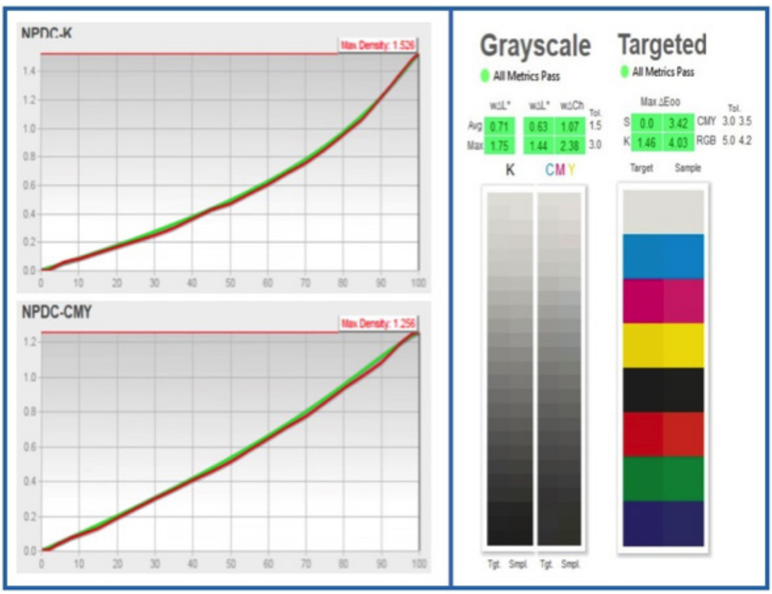


Figure 7: *Tonality and Gray Balance for Fingerprinting Run*

As seen from Figure 7, the measured Neutral Print Density Curve (NPDC) for both K and CMY were overlapping on Ideal curve represented in green line with minor deviation. The tolerances for G7® tonality (wΔL) and gray balance (wΔCh) were achieved and hence accomplishment of G7 Grayscale and Targeted Compliance.

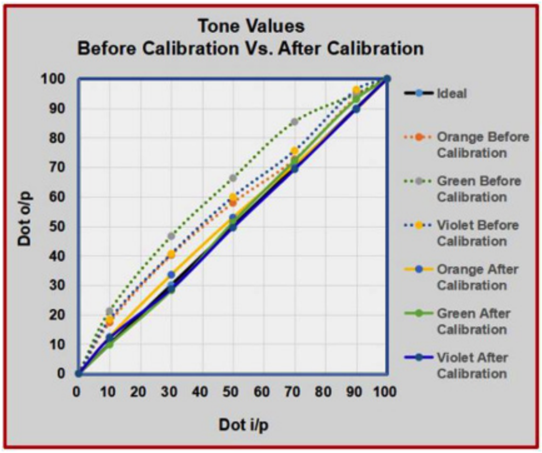


***Figure 8:** Tone Values of OGV Before and After Calibration*

Figure 8 shows successful calibration of OGV with Optimization Run referring to Before Calibration and Fingerprinting Run referring to After Calibration.

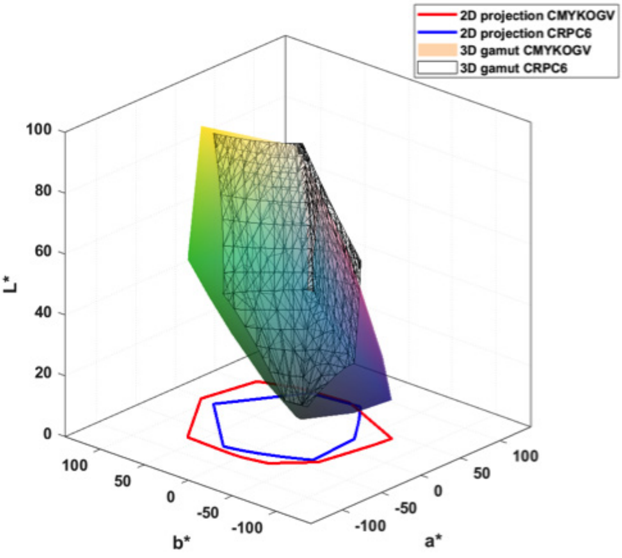


***Figure 9:** Gamuts of CMYKOGV (ECG) and CRPC 6*

The comparison between CMYKOGV gamut and the CRPC6 gamut (Figure 9) shows that some part of the CRPC6 gamut lies outside the ECG gamut between magenta and violet regions.

Description	Gamut Pair
Gamut 1	CMYKOGV
Gamut 2	CRPC6
Volume of Gamut 1	**639380**
Volume of Gamut 2	**389309**
Volume of intersection	380294
Absolute difference in gamut volumes	250071
Ratio of Gamut 1 to Gamut 2	**1.64**
Fraction of CMYKOGV gamut lying outside CRPC6	40.52%
Fraction of CRPC6 gamut lying outside CMYKOGV	2.32%

Note: All volumes are in cubic CIELAB units.

Table 3: *Gamut Analysis of CMYKOGV against CRPC6*

Table 3 compares the gamuts of CMYKOGV against the CRPC6 gamut. For each pair of gamuts, it shows the volume of intersection between two gamuts, gamut volume ratio and out-of-gamut volumes. It shows that the volume of CMYKOGV gamut is 64% bigger than the CRPC6 gamut. Around 41% of the CMYKOGV gamut is lying outside the CRPC6 gamut, whereas around 2% CRPC6 gamut is lying outside the CMYKOGV gamut.

There are total 1867 colors in Pantone Plus Solid Coated library. All of them were plotted in the CIELAB color space to compare against the CMYKOGV color gamut. Each color is analyzed to check if it is physically inside the gamut or outside by using Matlab. Out of 1867 colors, 1524 were found to be physically inside the CMYKOGV color gamut, which is around 82%. These 1524 in-gamut colors were selected for the Verification Run. A custom test-chart containing 1524 colors was prepared. These colors were then converted to 7-color separation using ECG color profile. The plates were made and printed on press using the identical press conditions to the Characterization Run. The printed test-charts were measured using i1 Pro 2 spectrophotometer.

The print results from the Verification Run revealed that the average color difference between the target and the measured spot colors was 0.42 DE2000, and 95th percentile colors below 2.49 DE2000. Out of 1524 colors, 92% of colors i.e. 1408 were below 2.0 DE2000, which is a typical tolerance for spot colors.

Conclusions

This study gives insights into the implementation of ECG for a narrow-web flexographic printing. The runs were conducted on a Nilpeter FB-430 flexography press with pre-determined press settings and identified parameters under controlled conditions using CMYKOGV UV inks on a white polypropylene self adhesive label stock. The work involved initial, optimization, fingerprinting, characterization and verification runs for the evaluation of spot colors. The results can be summarized as:

- 175 LPI plate screen ruling with AM screening was derived as an optimal combination of plate and anilox screening parameters during the Initial Run. The evaluation was done based on L* a* b* C* h* and dot structure analysis for the given set of anilox rollers for each ink.
- XCMYK reproduction was achieved during the Optimization Run.
- The Fingerprinting Run calibration was performed using G7 method for CMYK and a linear SCTV for OGV colors.
- The Characterization Run involved printing the custom-made CMYKOGV test chart to generate a ECG profile.
- The CMYKOGV gamut volume was found to be 64% bigger than the CRPC6 gamut, however a small 2% fraction of the CRPC6 gamut was outside the CMYKOGV gamut.
- Out of 1867 Pantone Solid Coated colors, 1524 colors were found to be physically inside the CMYKOGV Gamut. These 1524 colors were converted to the CMYKOGV ink builds and printed as a part of Verification Run. Overall accuracy of 1524 colors was very good with an average of 0.42 DE2000 between the target and printed colors.
- The results revealed that ECG printing is viable for a narrow-web flexographic process.

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